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April 12, 1962

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HUNTSVILLE, ALABAMA



# SOLDERING OF ELECTRICAL CONNECTIONS (HIGH RELIABILITY), PROCEDURE FOR

I. PURPOSE: This procedure establishes a standard process for hand-soldering of electrical connections.



II. SCOPE: This procedure specifies the methods, equipment, and materials that shall be used in soldering electrical connectors for space vehicles.

III. REFERENCES:

SPECIFICATIONS

Federal

| | |
|---|---|
| QQ-S-571 | Solder: Lead Alloy, Tin Lead Alloy, and Tin Alloy; Flux Cored Ribbon and Wire, and Solid Form. |
| O-E-760 | Ethyl Alcohol (Ethanol); Denatured Alcohol; and Proprietary Solvent |

Military

| | |
|---|---|
| MIL-I-7444 | Insulation Sleeving, Electrical, Flexible |
| MIL-I-22129 | Insulation Tubing, Electrical, Polytetrafluoroethylene Resin, Nonrigid |

PROCEDURES

George C. Marshall Space Flight Center

MSFC-PROC-257 Conformal Coating of Printed Circuit Assemblies, Procedure for

STANDARDS

George C. Marshall Space Flight Center

MSFC-STD-154 Printed Circuit Design and Construction, Standard for

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

IV. DEFINITIONS:

A. Terminal. - A terminal is a tie-point device used for convenience in making electrical connections. There are five basic styles of terminal:, (1) turret, (2) bifurcated, (3) eyelet, (4) hollow cylindrical, and (5) hook type.

1. Turret terminal. - A turret terminal is a round post-type grooved stud around which wires and leads are snugly hooked. It may have either spacing shoulders or grooves for positioning the leads.

2. Bifurcated terminal. - A bifurcated (split) terminal is a terminal containing a slot in which wires and leads are placed before soldering.

3. Eyelet terminal. - An eyelet (pierced) terminal is a terminal containing an eyelet or hole, through which leads (wires) are placed before soldering.

4. Hollow, cylindrical terminal. - A hollow, cylindrical solder-cup (pot) is a terminal that is designed to accommodate not more than one lead (wire) inserted into the open until lead (wire) "bottoms" in the receptacle.

5. Hook terminal. - A terminal formed in a hook shape; it is generally found on sealed relays.

V. RESPONSIBILITIES:

A. General.

1. MSFC Division responsibility. - Each division of Marshall Space Flight Center (MSFC) shall be responsible for implementing the provisions of this procedure. This procedure shall be applicable to all phases of electrical fabrication, assembly, and modification of space vehicles and ground support equipment components.

2. Deviations. - Requests to deviate from any requirement herein shall be supported by comprehensive test data to substantiate the reliability of the deviation and indicate why the deviation is necessary. No deviation to the requirements of this procedure shall be made until written approval is obtained from both the cognizant MSFC division and the MSFC Quality Assurance Division.

B. Quality Assurance Division.

1. The Quality Assurance Division shall be responsible for enforcement of the requirements of this procedure during fabrication, assembly, modification, repair, storage, and issue.

VI. SOLDERING PROCEDURES:

A. General requirements.

1. Materials.

a. Solder. - Solder used for soldering electrical connections shall conform to Federal Specification QQ-S-571, type AR. For general use, composition Sn 60 or Sn 63 shall be used.

b. Flux.

(1) Noncorrosive and nonconductive flux. - Only noncorrosive and nonconductive rosin-type fluxes shall be used. Rosin (or resin) core flux shall have a melting point below the liquid temperature of the solder. The use of liquid rosin-type flux having noncorrosive nonconductive properties is permissible for applications such as the removal of excess solder from a joint by wicking into strained wire, and for soldering nickel-plated wire. When used with flux-cored solder, the liquid flux shall be chemically compatible

with the solder core. Excess flux shall be removed from solder joints with the solvent specified herein.

(2) Corrosive flux. - The use of corrosive flux, conductive flux, paste flux, or acid-core solder is prohibited.

c. Insulation tubing.

(1) Flexible tubing. - Insulation tubing shall be clear, flexible polyvinyl-chloride sleeving conforming to type I of Specification MIL-I-7444. Polytetrafluoroethylene tubing conforming to Specification MIL-I-22129 shall be used in applications where extremely high temperature (220 degrees Fahrenheit(F) or higher) conditions necessitate usage. Tubing shall be slipped over all soldered terminals of relays, connectors, and similar items that are not protected by insulated grommets or by potting. The tubing shall extend a distance equal to or greater than the tubing diameter above the stripped portion of the attached conductor. All routed conductors in harness or box assemblies shall be protected at abrasion points by appropriate clear insulation tubing.

(2) Heat-shrink tubing. - Heat-shrink insulation tubing shall be shrinkable sleeving. The tubing shall be made of a material that does not emit gases or chemicals that are detrimental to the soldered joint, the wire, or the insulation of the wire. Heat-shrink tubing shall not be used on components where the application of heat will damage the component. The solder joint must be visible through the tubing to facilitate trouble-shooting and inspection.

d. Terminals. - Soldering terminals shall be of a metal, or shall have a plating, that will accept solder readily and require no pre-soldering preparation. Terminals shall be provided with guide slots, holes, grooves, or similar features to insure proper mating of the wire or wires with the terminals. Each terminal guide shall be located to facilitate the application of solder.

e. Solvent. - Solvent used for removal of grease, oil, dirt, or excess flux shall be ethyl alcohol conforming to Federal Specification O-E-760, grade I, class

A or B. The best commercial 99 percent pure (by volume) grade of isoprophyl alcohol is also acceptable.

f. Abrasives. - Emery cloth or aluminum oxide cloth of approximately Number 320 grit size may be used for cleaning unheated soldering iron tips. Power-driven abrasive cloth may also be used for this purpose.

g. Wire. - The wire size, number of strands, insulation resistance, insulation material, and wire plating shall be as shown on the electrical drawings and as required by the applicable specifications. For applications where high temperature (220 degrees F or higher) necessitates usage, polytetrafluoroethylene-insulated nickel-plated copper stranded wire shall be used. Excess wire shall be cut off prior to soldering the connection. Wire shall be cut to length before soldering, and the wire ends shall not extend beyond the connection. Stranded wire shall be twisted in its original form after insulation removal.

CAUTION

Silver-plated polytetrafluoroethylene-insulated wire is not acceptable because certain types of insulation react with flux and solder. This chemical reaction deteriorates the wire and contributes to breakage.

2. Tools.

a. Insulation strippers.

(1) Thermal stripper. - Use thermal type insulation strippers wherever practicable. Precision cutting type or other types of strippers shall only be used to strip glass braid and other insulation that cannot be removed otherwise.

NOTE

Only under certain conditions, such as sintering operations and the smoking of tobacco contaminated with polytetrafluoroethylene particles, are the pyrolysis byproducts of polytetrafluoroethylene considered a health hazard. Polytetrafluoroethylene must be heated to at least 400 degrees F before pyrolysis

byproducts are detectable. At a minimum temperature of 700 degrees F to 800 degrees F, byproducts that may conceivably cause "the shakes" (polymer fume fever) are detectable. To preclude the remote possibility of an ideal situation occurring when stripping polytetrafluoroethylene insulated wire with a thermal stripper, an exhaust hood and fan ventiliation system is recommended. (Should questions arise, consult the wire manufacturer.)

(2) Precision cutting type strippers. - Non-adjustable, factory-set, cutting-type, insulation strippers may be used when thermal strippers cannot be used; however, to prevent stretching the wire, avoid use on wire size 22 American Wire Gage (AWG) and smaller. The correct stripping hole for the corresponding gage of the wire shall be used. The setting of the cutter and the work produced shall be checked to assure that no nicks or cuts appear on the wire. Stripped wire with nicks or cuts shall not be used. Defective strippers shall not be used.

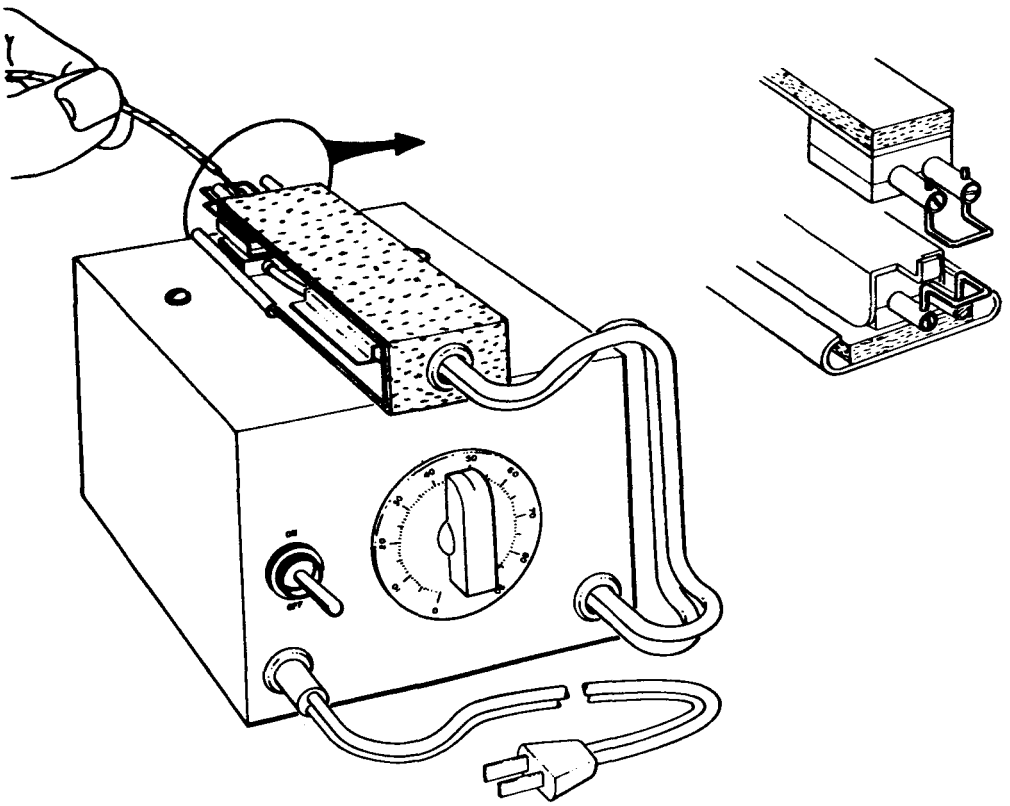


Figure 1. Thermal stripper.

(3) Other types of strippers. - Strippers other than the types mentioned may be used provided that the wire is not stretched, nicked, cut, or scraped.

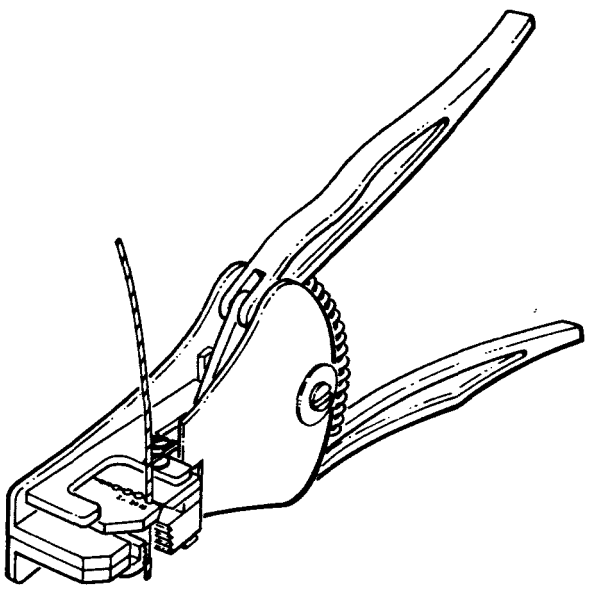


Figure 2. Precision cutting type stripper.

b. Bending tools. - Wire bending pliers or other devices may be used to form component leads. Long nose pliers shall be considered as an acceptable bending tool, provided that the sharp edges of the jaws are covered with durable tubing or plastic tape and do not nick, ring, or otherwise damage the wire (see figure 3).

NOTE

Exercise care to prevent component leads from being damaged or broken by the bending tools while they are being formed.

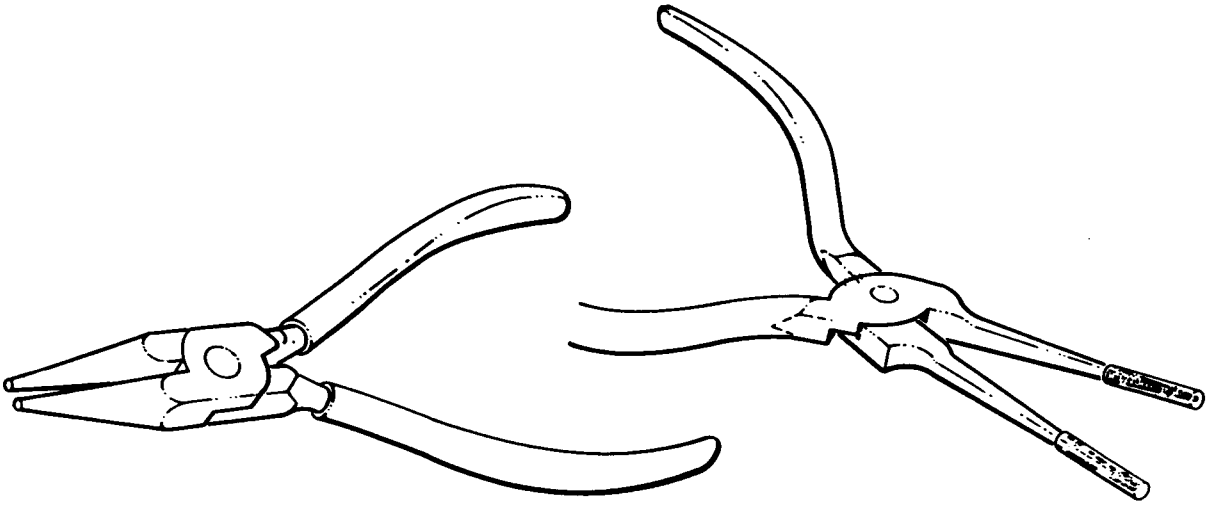


Figure 3. Proper bending tools.

c. Files. - Files for dressing copper tips shall be of the flat, fine, single-cut, shear-tooth type.

d. Thermal shunt. - Thermal shunts (or heat sinks) shall be of such material, size, and shape as to provide adequate protection to parts or components and to minimize interference to the soldering procedure (see figure 4). The thermal shunt shall be designed for rapid application and removal. It may be held in place by friction, spring tension, or by other suitable means which will preserve the finish and insulation of the wire and component being soldered. Thermal shunts shall be employed when soldering heat sensitive components, such as transistors and diodes.

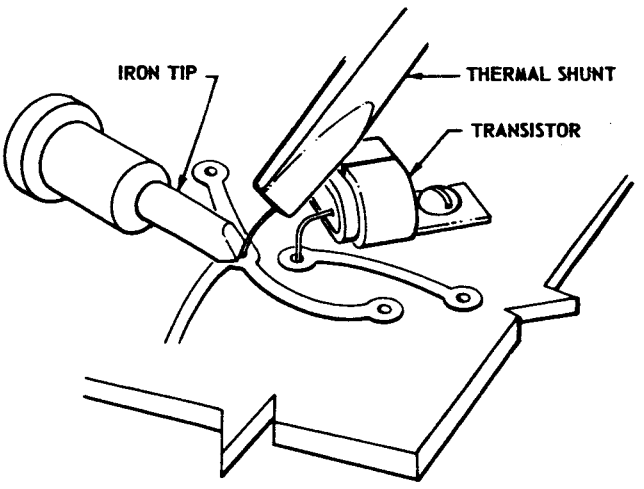



Figure 4. Thermal shunt.

e. Cleaning tool. - An efficient cleaning tool utilizing 1/2-inch copper shielding braid for cleaning of component leads can be constructed as shown in figure 5.

f. Brushes. - For cleaning contact areas before soldering and for removing excess flux following the solidification of the solder, a medium stiff natural or synthetic bristle brush shall be used. Wire brushes shall not be used.

g. Typewriter eraser. - For cleaning gold plating from printed circuit pads, a white pencil style typewriter eraser shall be used (see figure 6).

CAUTION

Remove only the gold plating and none of the copper to prevent altering the electrical characteristics of the printed circuitry.

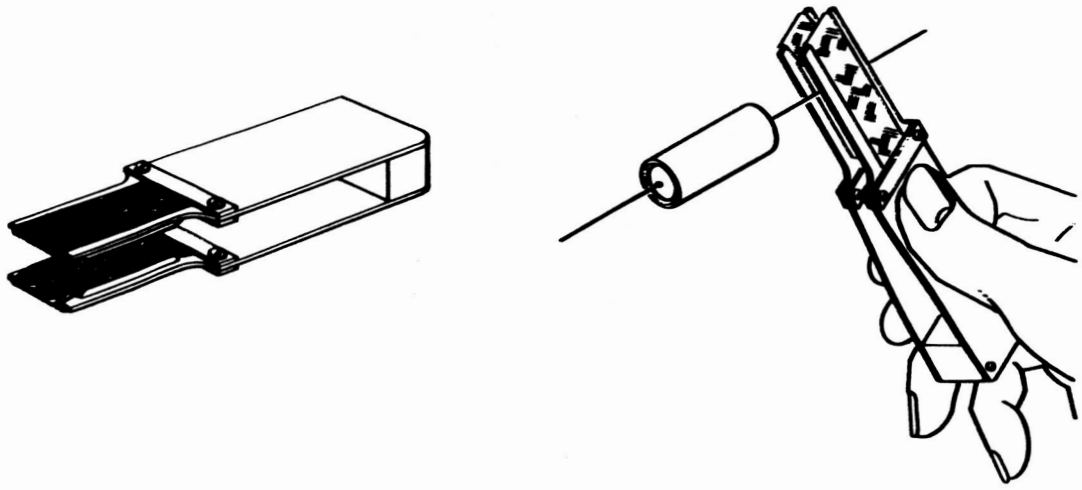


Figure 5. Cleaning tool.

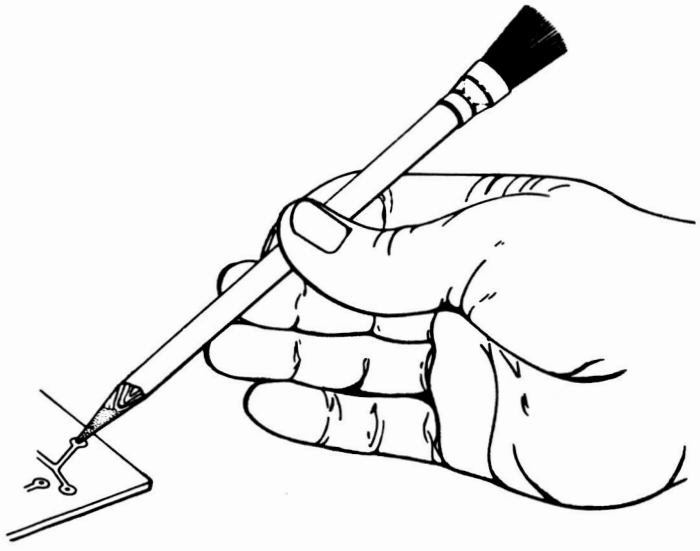


Figure 6. Cleaning circuit pad.

h. Soldering irons. - The soldering iron size, tip size, voltage rating, and wattage shall be carefully selected in relation to the work to be performed. Transformer-type solder guns shall not be used under any circumstance.

NOTE

A variable voltage supply is recommended for controlling the soldering iron temperature when soldering printed circuits. Temperature control is advantageous in many other soldering applications. By proper selection of tips and correct voltage adjustment, a single 50-watt pencil-type soldering iron can be used for soldering miniature printed circuits or relatively large terminals.

i. Soldering iron tips. - Copper or MSFC approved plated tips shall be used.

NOTE

For best results, the unplated copper tip is recommended.

3. Preparation for soldering.

a. Cleanliness.

(1) Area and workbench. - The work area and workbench shall be maintained in a clean and orderly condition. All dirt, grease, oil, solder splatter, wire and insulation cuttings, and foreign matter shall be promptly removed.

(2) Tools. - All dirt, grease, oil, and other foreign matter shall be removed from the tools.

(3) Component leads and terminals. - Component leads and terminals shall be protected by suitable packaging and by minimum handling prior to use.

b. Environmental conditions. - All soldering shall be performed in an environmentally controlled electronic assembly clean room. The minimum requirements of this room are as follows:

(1) Air conditioning.

(a) Temperature limits. - Commercial air conditioning designed for a 20 degree F temperature differential is adequate.

(b) Humidity limits. - The relative humidity shall be 40 percent plus or minus 10 percent.

(c) Pressure differential. - In order to eliminate infiltration of dust-laden air, a positive pressure differential shall be maintained within the room.

(2) Air filtration.

(a) Method. - The method of air filtration is optional; however, it shall meet the requirements below.

(b) Design criteria.

(i) Particle count method. - The National Bureau of Standards discoloration test shall be used.

(ii) Particle count tolerance. - The particle count method shall be 85 percent efficient.

(c) Operating criteria.

(i) Particle collection method. - The Greenberg-Smith Impinger collection method or equivalent shall be used.

(ii) Particle count method. - The power microscope, light field technique shall be used.

(iii) Particle count tolerance. - The tolerance shall be 250 thousand countable particles per cubic foot of air.

NOTE

The total count will include all particles visible with the prescribed equipment and technique. The smallest particle seen by the 10-power microscope, light field technique is about 0.9 microns in size.

(3) Facility design factors. - The facility should be designed and constructed with a view to a high standard of shop cleanliness and the lowest degree of maintenance. It is recommended that construction costs be in keeping with the projected work load.

(a) Floors. - Floors shall be finished with rubber tile or other grease resistant material. To preclude future dirt problems, insure a strong permanent bond between the floor covering and the subsurface.

(b) Interior finish. - All walls, ceilings, and painted fixtures shall be painted with materials of sufficient quality to provide a tough, smooth, dust resistant surface that will be resistant to chipping, flaking, and powdering.

(c) Utilities and fixtures. - Standard utilities, fixtures, and furniture shall be installed throughout. Lightning arrangements shall provide a minimum of 75 foot-candle shadowless illumination on working surfaces.

(4) Special considerations.

(a) Every consideration should be given to installation and arrangement of furniture and fixtures that will keep floors, corners, aisles, or workbenches clear and uncluttered, thus, facilitating frequent, easy, and thorough cleaning.

(b) A central vacuum-cleaning system capable of wet or dry pickup should be installed to service the work area. Only flexible plastic vacuum hoses shall be used. Provisions for emptying the dust tank shall be such that the clean room or the intake air will not be contaminated.

(c) Since most contamination will be brought into the clean room on shoes, adequate facilities for scaping, brushing, and wiping dirt off shoes of personnel shall be provided.

(d) Fully filtered air and 100 percent exhaust shall be provided to parts cleanup areas where toxic or volatile vapors are generated.

c. Soldering iron tip maintenance. - The soldering iron tip shall always be checked for tight attachment to the iron. Oxidation scale shall be removed at frequent intervals to insure proper transfer of heat from the heating element to the tip. A bright, thin but continuous tinned surface shall be maintained to avoid transfer of impurities to the solder joint.

d. Cleaning and tinning the iron.

(1) Cleaning copper tips. - While the copper tip is cold, use a single-cut flat file to dress and shape the tip. After filing, heat the soldering iron, and when the tip reaches the lowest temperature required to melt the solder, apply solder to the tip. While the tip is hot, it may be cleaned by wiping lightly on a wet, fine texture natural or synthetic sponge.

(2) Cleaning plated tips. - Clean plated tips with emery cloth or aluminim oxide cloth by polishing (while the tip is cold) until the surface is bright. A file shall not be used. While the tip is hot, it may be cleaned by wiping lightly on a wet fine texture natural or synthetic sponge.

e. Preparation of conductors.

(1) Insulation removal. - Whenever possible, employ a thermal stripper to remove insulation from conductors (see paragraph VI.A.2.a.). Conductors shall not be ringed, nicked, cut, stretched, or otherwise damaged by the insulation stripping operation.

(2) Insulation clearance. - Wires having an insulation outside diameter greater than 1/32-inch shall have a minimum clearance between the terminal and the wire insulation of 1/32-inch and a maximum clearance equal to the insulation outside diameter plus 1/32-inch. Wires having an insulation outside diameter of less than 1/32-inch shall have a minimum clearance equal to the outside diameter of the insulation and a maximum clearance of 1/32-inch.

(3) Tinning conductors. - All portions of stranded wires coming in contact with the soldered area shall be tinned by the assembler as illustrated in figure 7, or by other MSFC approved methods. A thermal shunt shall be used to prevent the solder from wicking under the insulation. Tinning on wire shall extend at least far enough to take full advantage of the depth of the terminal or solder cup. Form the "hook" after tinning.

(4) Vibration bend. - All wires or leads terminated at a solder connection shall have sufficient slack in the form of a gradual bend. In applications where multiple wires are routed from a common cable trunk to equally spaced terminals, the vibration bends shall be uniform in length to prevent stress on any one wire (see figure 8).

NOTE

Vibration bends shall not be construed to be service loops.

(5) Solid hookup wire. - Solid hookup wire or solid bus wire shall not exceed 5/8-inch length between solder connections. This requirement does not apply to components with solid wire leads.

(6) Splicing. - Unless otherwise specified, the splicing of conductors in prohibited.

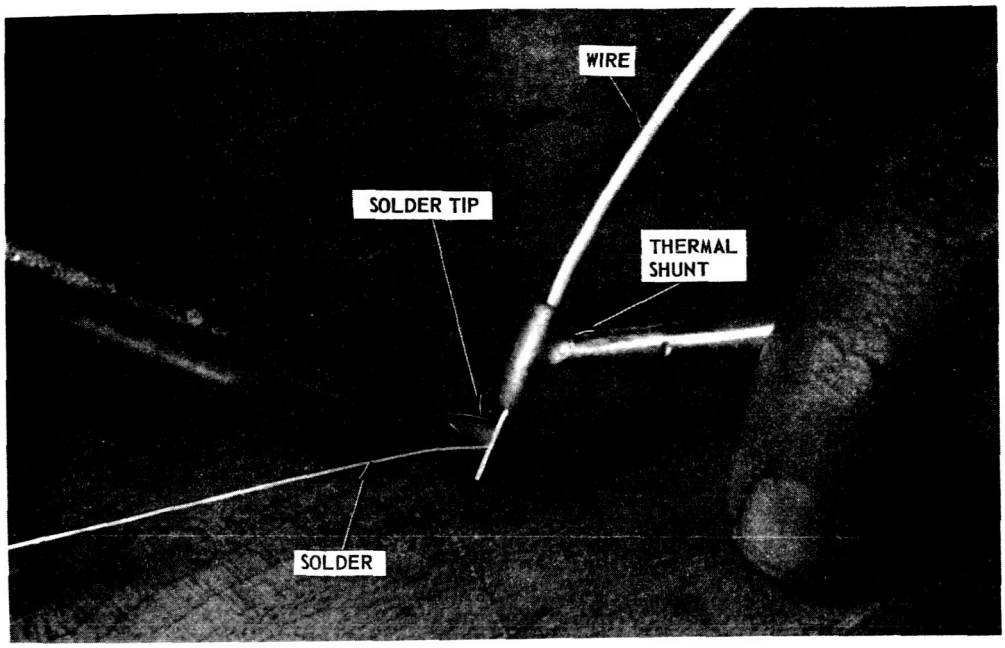



Figure 7. Correct method for tinning (wire).

f. Personnel. - Unless otherwise specified, all personnel performing the soldering functions specified herein shall be certified in accordance with the appendix of this precedure (certification).

4. Soldering.

a. Connection. - After tinning and forming of the wire, the parts to be joined shall be placed or held together so that parts do not move during the soldering process. The solder joint shall not be disturbed during the solidification of the solder.

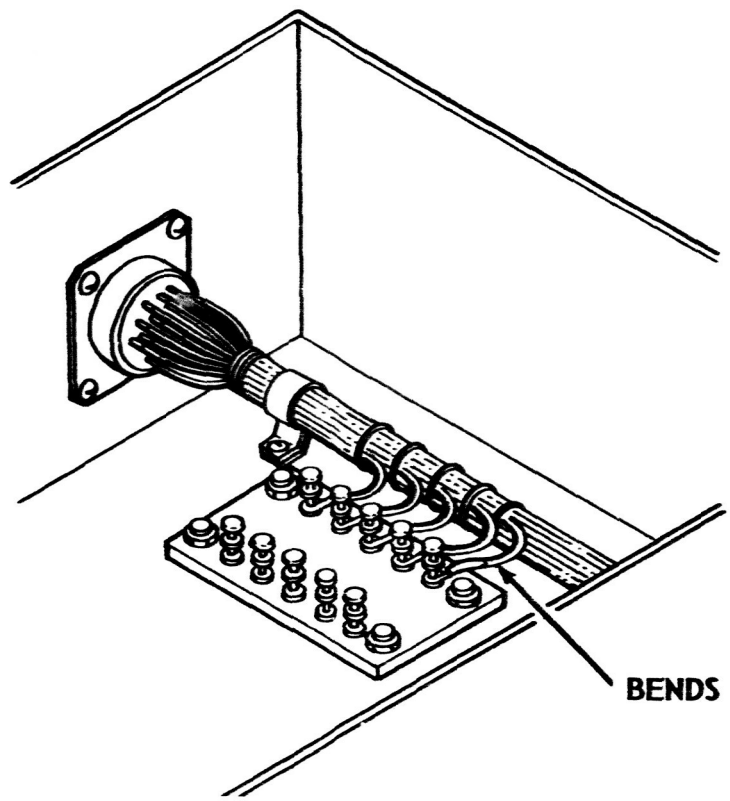
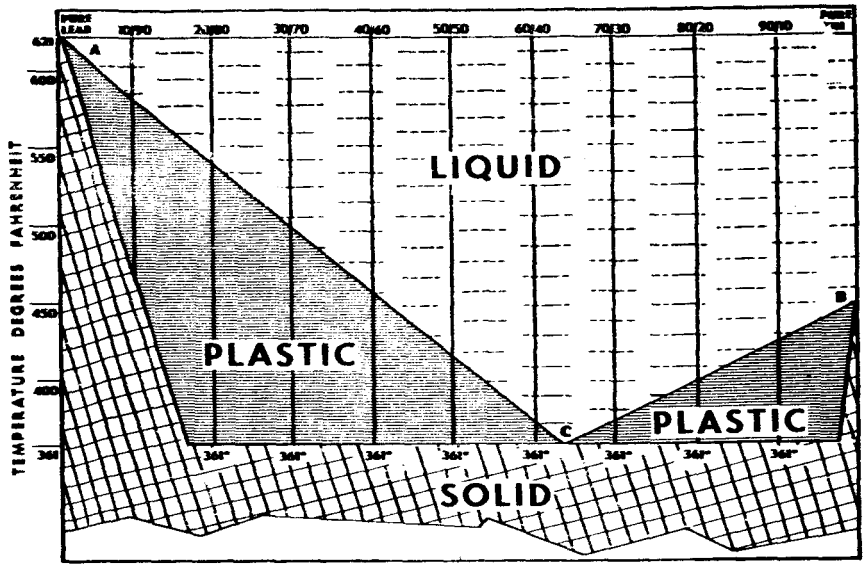



Figure 8. Vibration bends.

b. Heat application. - Apply the soldering iron tip to the connection area in such a manner that optimum heat will be transferred to the parts to be soldered and, at the same time, protection will be provided to the insulation and to heat-sensitive components. Do not overheat the joint area. See figure 9 for the approximate melting points of solder.

c. Solder application. - Solder shall be applied to the connection area when the temperature of the parts will melt the solder readily. Avoid melting the solder against the soldering iron tip. The iron shall be tilted sufficiently to permit application of the solder directly to the heated wire and terminal. Sufficient solder shall be applied to cover the joint, but application of excessive solder shall not be allowed. Dip soldering is prohibited as a method for attaching component leads.




| %Sn | %Pb | %Ag | %Sb | Temperature at which solder becomes plastic C° | Temperature at which solder becomes plastic F° | Temperature at which solder becomes liquid C° | Temperature at which solder becomes liquid F° |
|---|---|---|---|---|---|---|---|
| 0 | 100 | | | | | 327 | 620 |
| 5 | 95 | | | 272 | 522 | 314 | 597 |
| 10 | 90 | | | 224 | 435 | 302 | 576 |
| 15 | 85 | | | 183 | 361 | 290 | 554 |
| 20 | 80 | | | 183 | 361 | 280 | 536 |
| 25 | 75 | | | 183 | 361 | 268 | 514 |
| 30 | 70 | | | 183 | 361 | 257 | 496 |
| 35 | 65 | | | 183 | 361 | 247 | 477 |
| 38 | 62 | | | 183 | 361 | 242 | 468 |
| 40 | 60 | | | 183 | 361 | 238 | 460 |
| 45 | 55 | | | 183 | 361 | 225 | 437 |
| 48 | 52 | | | 183 | 361 | 218 | 424 |
| 50 | 50 | | | 183 | 361 | 212 | 414 |
| 55 | 45 | | | 183 | 361 | 200 | 392 |
| 60 | 40 | | | 183 | 361 | 188 | 370 |
| 63 | 37 | | | Eutectic | | 183 | 361 |
| 65 | 35 | | | 183 | 361 | 184 | 364 |
| 70 | 30 | | | 183 | 361 | 186 | 367 |
| 75 | 25 | | | 183 | 361 | 192 | 378 |
| 80 | 20 | | | 183 | 361 | 199 | 390 |
| 85 | 15 | | | 183 | 361 | 205 | 403 |
| 90 | 10 | | | 183 | 361 | 213 | 415 |
| 95 | 5 | | | 183 | 361 | 222 | 432 |
| 100 | 0 | | | | | 232 | 450 |
| 95 | | | 5 | 232 | 450 | 238 | 460 |
| 35 | 63 | | 2 | 187 | 369 | 237 | 459 |
| 27 | 70 | 3 | | 179 | 354 | 312 | 594 |
| 40 | 57 | 3 | | 179 | 354 | 289 | 543 |
| 50 | 47 | 3 | | 179 | 354 | 260 | 500 |
| 61.5 | 35.5 | 3 | | 179 | 354 | 248 | 478 |
| 62.5 | 36.1 | 1.4 | | Eutectic | | 179 | 354 |
| 96 | | 4 | | Eutectic | | 221 | 430 |
| 95 | | 5 | | 221 | 430 | 240 | 465 |
| | 97.5 | 2.5 | | Eutectic | | 305 | 581 |
| | 95 | 5 | | 305 | 581 | 365 | 689 |
| 0.75 | 97.5 | 1.75 | | Eutectic | | 310 | 590 |

*A eutectic alloy is that composition of two or more metals that has one sharp melting point and no plastic range. Sn-Tin; Pb-Lead; Ag-Silver; Sb-Antimony.*

Figure 9. Tin-lead fusion diagram and melting temperature of alloy used in soldering.

d. Appearance. - A solder joint shall have a shiny bright appearance, no porosity, good fillet between conductors, good adherence to both parts, and no excess flux or solder. In all applications except those involving connector cups, the contour of the wire shall be visible after soldering as shown in figure 10.

e. Soldering aids. - Soldering aids or other tools shall not be used to exert force on wires. The quality of a properly cleaned solder connection can be determined by a visual inspection. The practice of bending or pulling wires to ascertain security of the connection can prevent a serious reliability hazard.

B. Special requirements.

1. Connectors, wire, cable, and harness assemblies.

a. Size. - Cups (solder pots) shall be of sufficient size to accommodate the attached conductors. Cups shall not be modified to accept oversize conductors. Conductor sizes shall not be reduced to permit use of under size solder cups.

b. Splice. - Unless otherwise specified, splicing of conductors is prohibited.

c. Termination of wires. - All conductors terminating in a connector cup (solder pot) shall bottom in the cup.

d. Solder joint. - The solder shall completely fill the cup and follow the contour of the cup entry slot. No solder shall spill over and adhere to the sides of the cup (see figure 11).

NOTE

This connection may be made with either a resistance or conduction type soldering tool. When a conduction type iron is used, a slight tinned effect will usually occur at the point where the iron tip contacts the base of the cup. This condition is normal and shall not be cuase for rejection provided there are no peaks, globules, or excessive buildup of solder.

e. Flux. - After soldering, excess flux shall be removed from cups and connectors with the solvent specified herein.

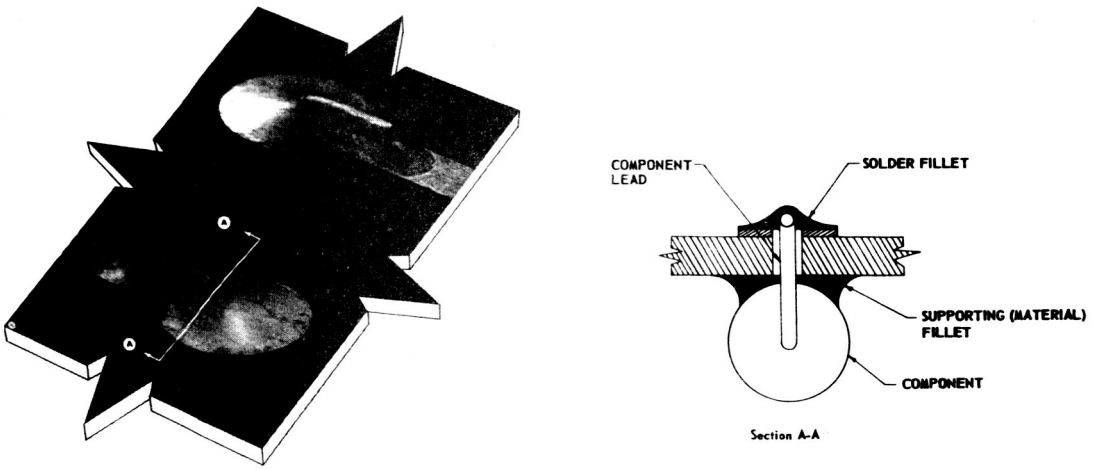



Figure 10. Good solder joint.

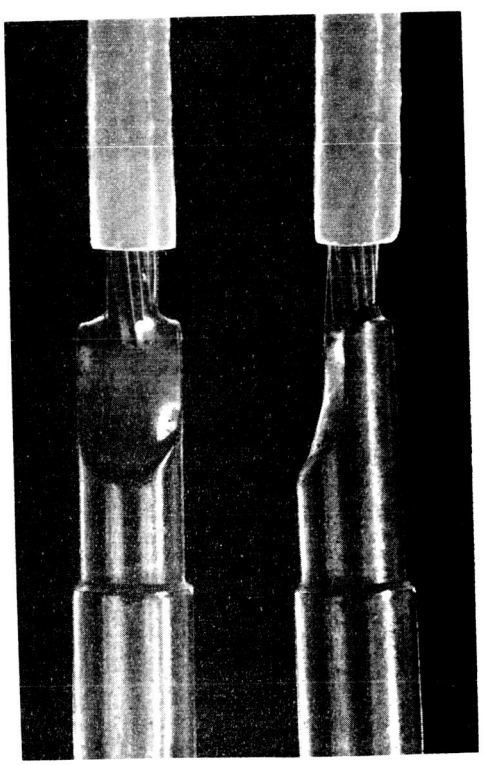


Figure 11. Good solder cup connection.

f. Wicking. - Slight wicking shall be acceptable on wires that are adequately supported by clamps, lacing, or potting compound. In certain applications, slight displacement or flexing of wires to gain access to otherwise inaccessable calibration or modification points may be unavoidable. Wires in this category shall not be wicked.

NOTE

Flexing of wire, however slight, is not recommended. Design precautions should be taken to minimize, and where possible, eliminate the necessity of displacing or flexing wire.

g. Insulation damage. - Insulation shall not show evidence of damage by excessive heat from the soldering operation. Slight discoloration as a result of thermal stripping is permissible.

2. Turret and bifurcated terminals.

a. Size. - Terminals shall be of sufficient size to accommodate the conductors. Terminals or slots shall not be modified to accept oversize conductors. Conductor size shall not be reduced to accommodate undersize terminals.

b. Splice. - Unless otherwise specified, splicing of conductors is prohibited.

c. Mounting. - Terminal mounting holes shall be punched or drilled to a diameter that will provide a snug fit between terminal shank and mounting hole. A 360-degree contact between the mounting shoulder of the terminal and the board shall be maintained. The terminal board shall be free of cracks, cuts, scracthes, delamination, or other damage.

d. Bus bar. - All terminals mounted on bus bars shall be soldered to the bar after swaging.

e. Swaging of terminals. - A rolled swage shall be used when the swage is terminated directly to the terminal board or non-circuit side of a printed circuit board. a "V" or funnel swage shall be used when the swage is terminated in contact with a printed circuit pattern. After swaging, the roll or flare shall not be split.

f. Solder joint. - A minimum amount of solder shall cover the top of the conductor, and a slight fillet shall be formed between the lower half of the conductor and the terminal. The contour of the conductor shall be visible after soldering. The end of the attached conductor shall not extend beyond the terminal base dimensions, and exposed copper on the conductor ends shall be covered with solder (see figure 12).

g. Flux. - After soldering, any excess flux shall be removed from the terminals and boards with the solvent specified herein.

3. Connections.

a. Turret terminal. - A half-wrap (180 degrees) shall be used to attach wires to base of terminal; however, design consideration may require the wire to be soldered to the top shoulder or the positive guide slot. The side routes shall be used on all solid post turret type terminals (see figure 12).

NOTE

The wrap may be increased to 270 degrees on wires AWG 28 and smaller.

NOTE

Insulation clearance shall be referenced from the base.

b. Bifurcated terminal.

(1) Bottom route. - Wires, AWG 26 and larger, shall terminate with a 90-degree bend and shall be soldered to the terminal shoulder. Wires, AWG 28 and smaller, may be bent to lie along the face and one side of the vertical post. (See figure 13.)

NOTE

The insulation clearance shall be measured from the point of entry of the wire into the terminal.

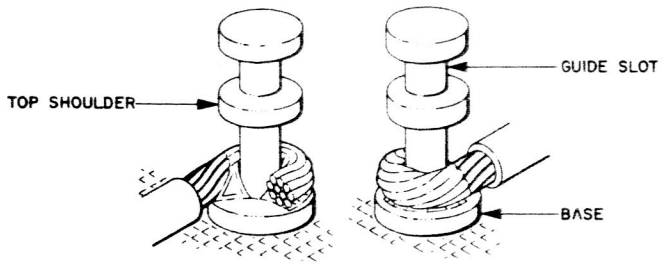



Figure 12. Solid turret terminal.

(2) Side route. - The wire shall enter the mounting slot at a right angle and be terminated with a 90-degree bend. The direction of the 90-degree bend on each additional wire shall alternate (see figure 14). The first wire shall be soldered to the base and the vertical post. Additional wires shall be soldered as close as possible to the preceding wire maintaining a clearance between the stranded wire equal to the thickness of the two insulations. All conductors or wires shall be confined within the lower 80 percent of the terminal as shown in figure 12. The top 20 percent of the terminal shall not be used. On wire AWG 28 and smaller, the wrap may be increased to 180 degrees.

NOTE

Insulation clearance shall be referenced from the base. The insulation on the first wire and all additional wires shall be a uniform distance from the terminal posts.

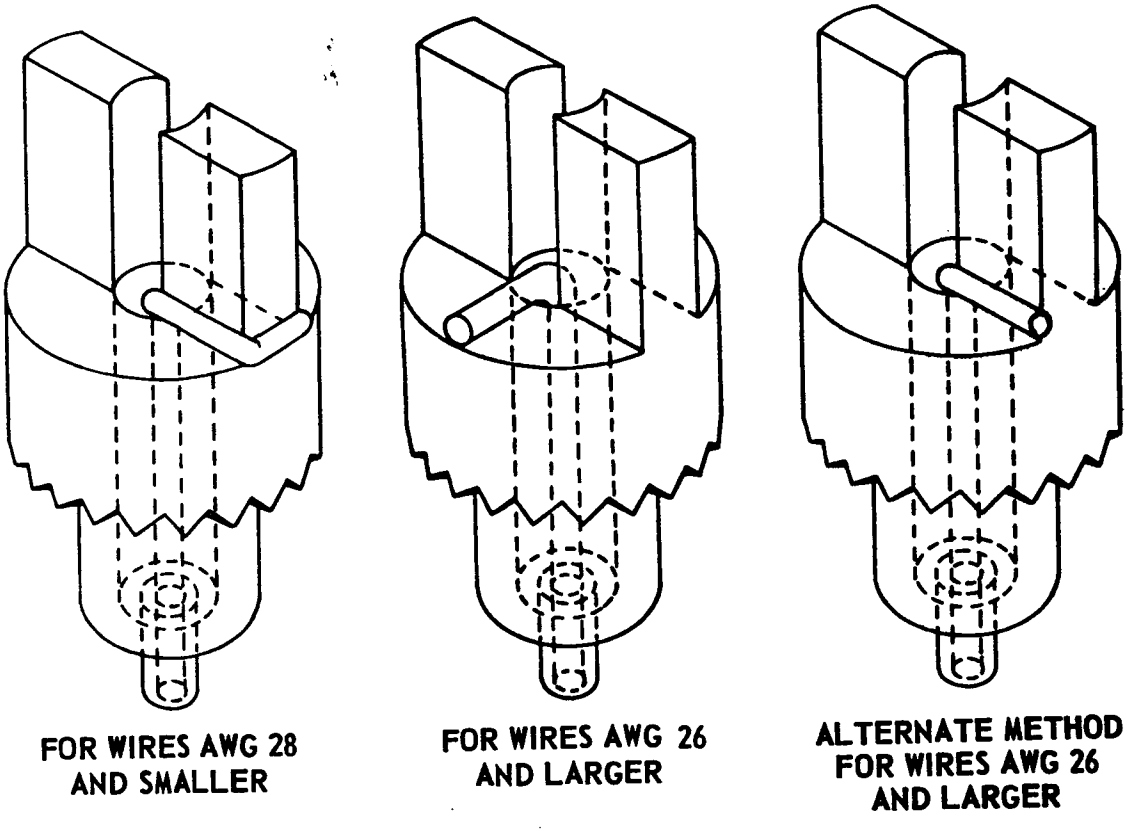



Figure 13. Sketch showing bottom routing of conductor into bifurcated terminal.

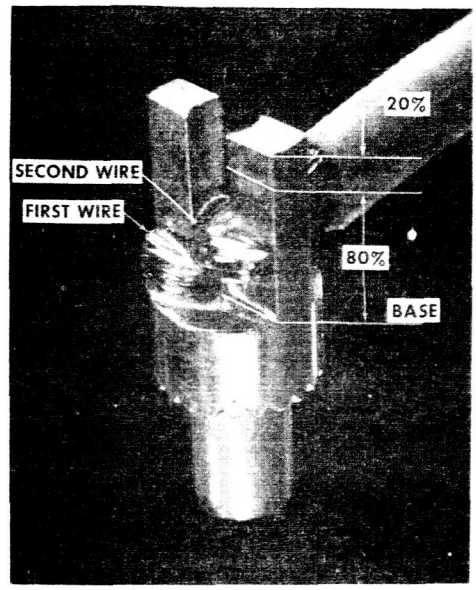


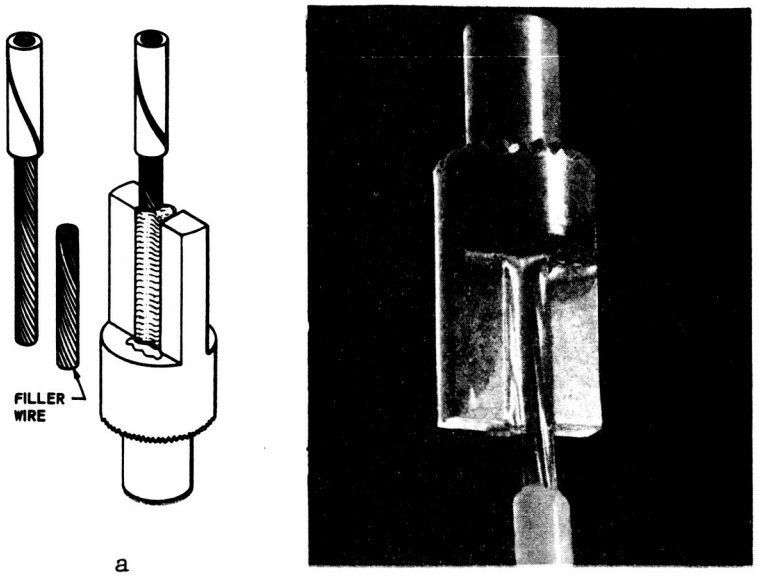

Figure 14. Alternate connections.

(3) Top route. - The wire should be stripped and tinned prior to connecting and should be accompanied by a stranded, tinned "filler" wire while soldering to help hold the wire in position (see figure 15a). (See figure 15b for finished product.) A large conductor which fills the gap will require only solder fillets for retention.

NOTE

The insulation clearance shall be measured from the point of entry of the wire into the terminal

(4) Spare terminals. - All spare through-hole terminals shall be closed (bridged) with solder when potting of the chassis is required.




a b

Figure 15. Top route.

4. Hook or perforated terminals for relays and connectors.

a. Size.

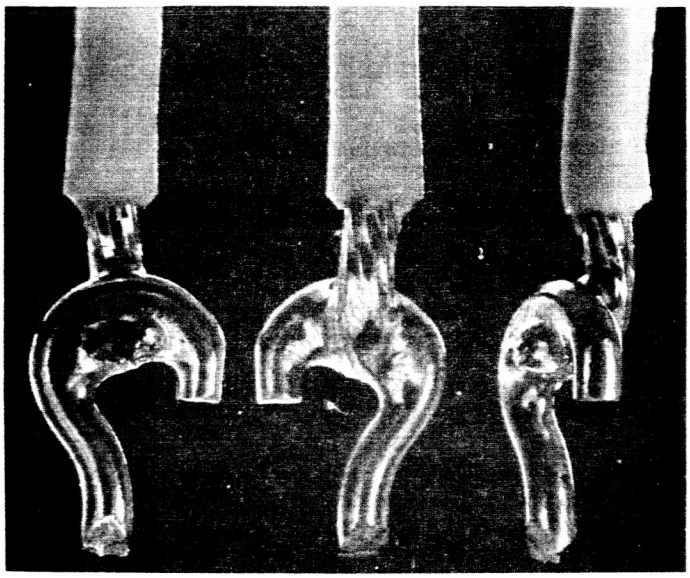
(1) Terminals. - Terminals shall be of sufficient size to accommodate the attached conductors. Modifying or enlarging the terminal or slot to accept over-size conductors shall not be permitted.

(2) Wire. - The diameter of the wire shall not be reduced.

b. Splice. - Unless otherwise specified, splicing of conductors is prohibited.

c. Solder joint. - A minimum amount of solder shall cover the wire, and the solder shall form a slight fillet between the terminal and each side of the wire. The contour of the wire shall be visible after soldering (see figure 16).

d. Wires. - Wires shall be attached to hook or perforated terminals by forming the tinned wire to at least a 90-degree angle before soldering.



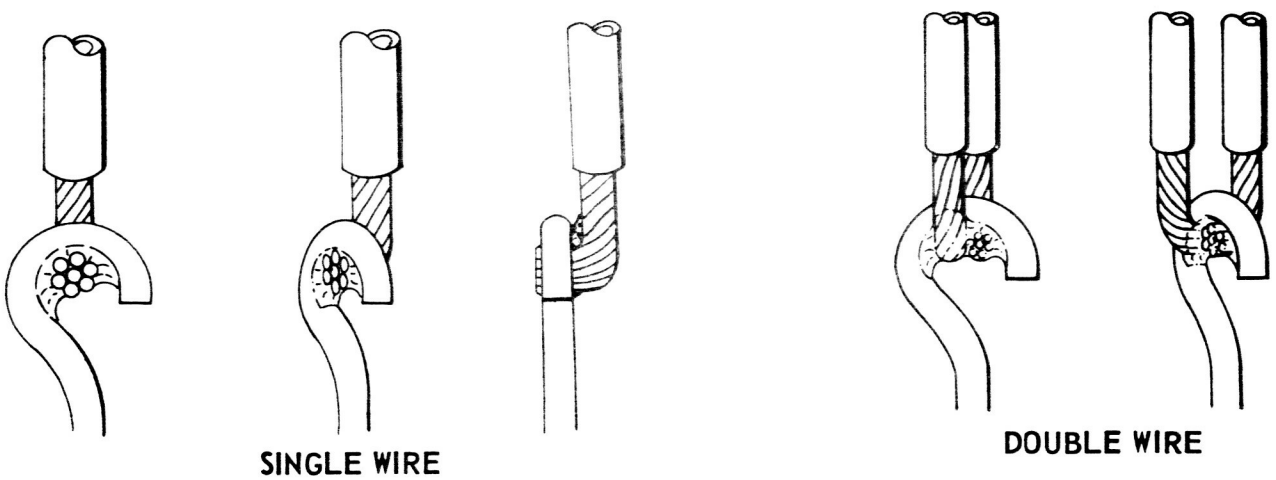



Figure 16. Solder joints on hook terminals.

5. Printed circuits.

a. Printed conductor plating and coating. - The plating or coating on printed conductors shall not be detrimental to the homogeneous structure of solder and shall aid, rather than hinder, the intermetallic action of copper and solder. Tin-lead coating is preferred on circuits that must be soldered.

(1) Plating (gold). - Printed connector contacts (fingers), printed switch contacts, and other wiping surfaces that require a relatively hard plating shall be gold plated in accordance with Standard MSFC-STD-154. If gold plating is used on circuit pads, or other areas that require soldered connections, it shall be removed unless the solderability of the gold plating is determined as outlined below. Completed solder joints shall exhibit the characteristics defined in (a) and (b) (i).

(a) Solderability (peel-pull) test for gold plated circuitry.

(i) A test printed circuit board, conforming to the general configuration of figure 17, shall be processed and plated with each lot of production boards. The test board shall be fabricated from a portion of the same material used for the production boards.

(ii) Twenty pieces of tinned copper bus wire, or equivalent, approximately 0.020 inch in diameter and 8 inches long shall be soldered to the circuit pattern as shown in figure 18. The solder should cover approximately 1/4 inch of the wire and circuit.

(iii) Mount the board on an accurate pull-stress machine that is calibrated from zero to 10 pounds. The board shall be mounted to permit a near vertical pull on the wire.

(iv) Operate the pull-stress machine at a speed of 0.5-inch-per-minute. The minimum pull required to separate the wires from the circuit shall not be less than 4 pounds. Each wire shall leave a groove in the solder and the bulk of the solder joint shall remain attached to the circuitry. (See figure 19.)

(b) Characteristics and appearance of solder joint on gold plated circuit.

(i) The solder joint shall exhibit:

a. A bright metallic luster.

b. A close fine-grained texture.

c. A low dihedral angle of wetting (see figure 20).

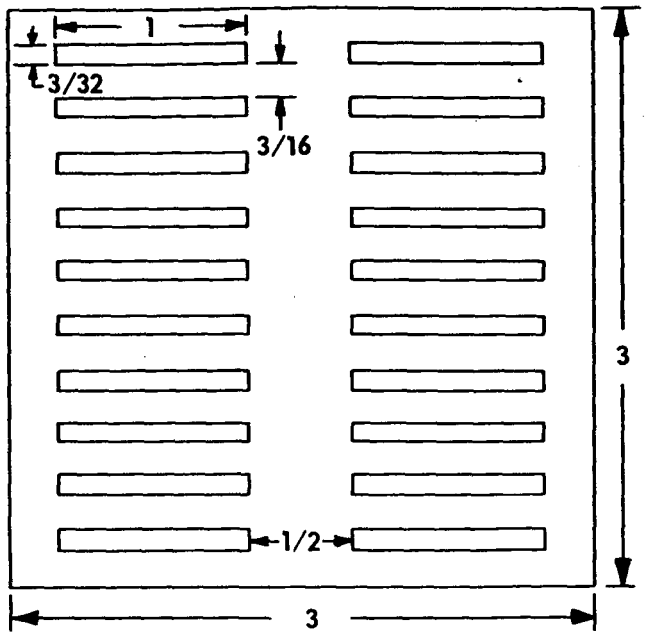
(ii) Evidence of any of the following defects in the solder joint shall be cause for rejection:

a. Dewetted areas that exceed 10 percent of joint.

b. Porosity

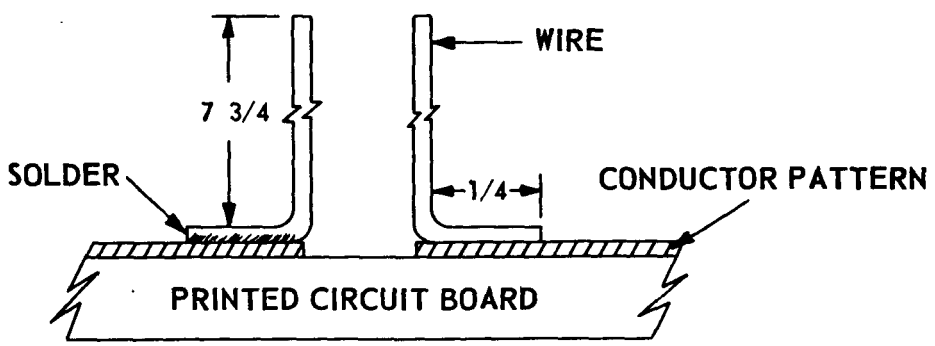
c. Surface stress patterns in the solder matrix.

(2) Coating (tin-lead). - Tin-lead coating is the preferred surfacing material on circuit pads and other areas that require soldered connections. When this coating is used, the conductive pattern shall be coated with composition SN63 solder conforming to Specification QQ-S-571. Use the hot-dip procedure described below to apply the coating; electro-deposited tin-lead plating shall not be acceptable.




NOTE: ALL DIMENSIONS ARE IN INCHES

Figure 17. Design test printed circuit board.




NOTE: ALL DIMENSIONS ARE IN INCHES

Figure 18. Soldering tinned copper wire to circuitry.

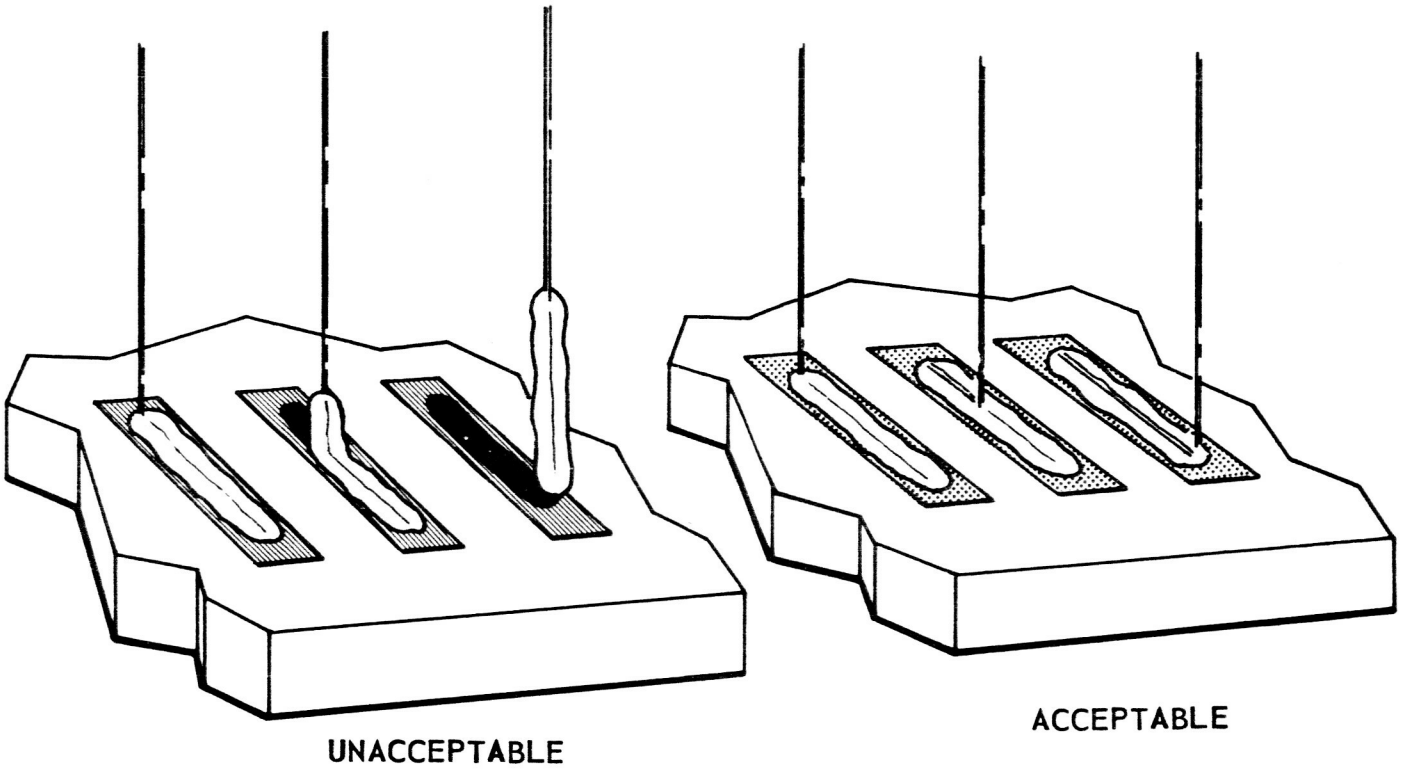



Figure 19. Solder connection peel-pull test.

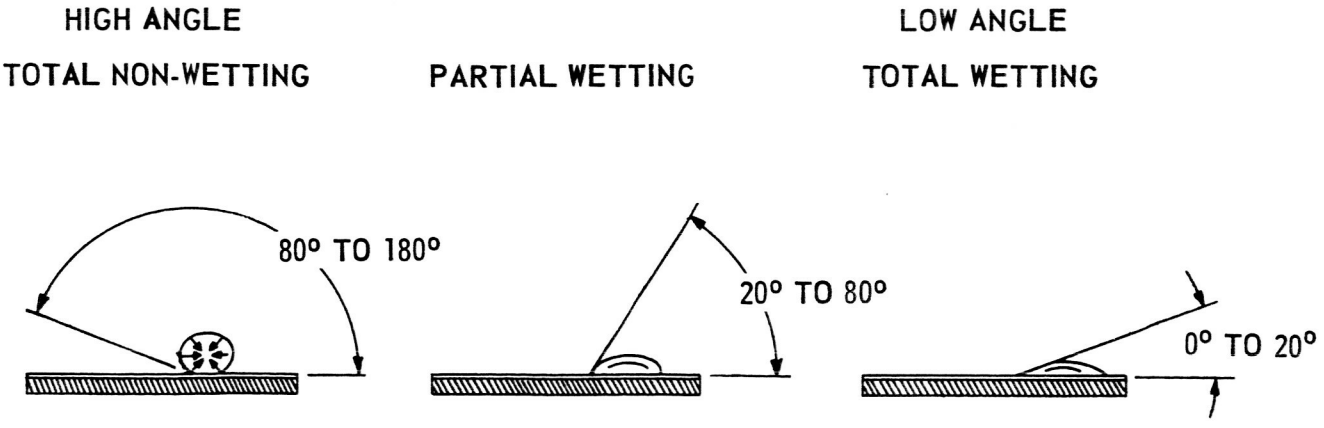



Figure 20. Dihedral angle of wetting.

(a) Procedure for applying tin-lead coating.

(i) Mask printed connector contacts (fingers), printed switch contacts, and other wiping surfaces that are hard gold plated to prevent contact with the solder bath.

(ii) To ensure that all ink and Kodak Photo Resist, or approved substitute, has been removed hand scrub or brush machine wash the printed circuit board.

(iii) Immerse the board in a solution of APC Bright Dip No. 1 (manufactured by Amchem Products, Inc., Ambler, Pennsylvania), or equivalent, and mildly agitate for 10 to 15 seconds.

(iv) Rinse the board with a spray of warm demineralized water for 30 to 45 seconds, and dry with oil- and moisture-free compressed air.

(v) Immerse the board in a 16-percent hydrochloric acid and demineralized water solution for 30 to 45 seconds (the solution should be made by diluting 31-percent hydrochloric acid, technical grade, with demineralized water).

(vi) Rinse the board thoroughly with warm demineralized water for one minute and dry with oil- and moisture-free compressed air.

(vii) When dry, immediately place the printed circuit board in a "hand slinger" and dip in flux. Then, dip the board in a hot solder bath (surface free of dross and oil) at 456 degrees F to 500 degrees F for 3 to 5 seconds.

NOTE

An automatic centrifuge type "slinger" with controllable spin speed and board immersion time may be used in lieu of the "hand slinger" method. The centrifuge method will provide better control over coating thickness and will produce a smoother finish.

(viii) Shift the printed circuit board, while immersed, to the other side of bath and remove it from the bath through a thin film of peanut oil. Immediately sling the assembly in the "hand slinger" to remove excess solder. The final tin-lead coating thickness shall be 0.0015 (plus or minus 0.0005) inch.

NOTE

The solder bath surface where the printed circuit boards are immersed shall be cleaned prior to each coating operation. Exercise care to prevent the peanut oil from migrating over the total surface area of the solder bath because solder will not properly adhere to the printed circuit conductors if the board is immersed through a film of peanut oil.

(ix) Wash the printed circuit board in the solvent specified herein to remove residual flux and peanut oil.

(x) Place and seal the circuit boards in bags for protection during handling or storage.

b. Presoldering and postsoldering requirements. - An inspection of the printed circuit board shall be made before mounting the components to be soldered and after the soldering operation has been completed. The presence of any of the following defects shall be cause for rejection of the board:

(1) Pits, scratches, or undercutting that reduce the conductor cross-sectional area more than 20 percent.

(2) Separation of the conductor pattern from the base laminate.

(3) Blisters in the conductor pattern.

(4) De-lamination of the base material.

(5) Wrinkles in the conductor pattern.

(6) Dirt, grease, or other foreign matter on the printed circuit board.

(7) Clinched leads that result in a reduction of the required spacing between conductors.

(8) Scratched, abraided, or scraped epoxy finish that will diminish the electrical resistance.

c. Soldering and assembly requirements.

(1) Cleaning. - Regardless of visual appearance, all component leads and terminals shall be cleaned immediately prior to soldering.

(2) Use. - After component leads have been cleaned they shall be mounted and soldered to the circuit before any appreciable reoxidation occurs.

(3) Lead bending. - To prevent damage, component leads shall be bent with a round smooth-finished tool (see figure 3). The radius of the bend shall be equal to or greater than twice the lead diameter. The minimum distance from component end seal to the start of the bend shall be 1/16 inch (see figure 21). On components that have a welded lead, such as tantalum capacitors, the start of the bend shall be 1/16 inch or more from the weld (see figure 22).

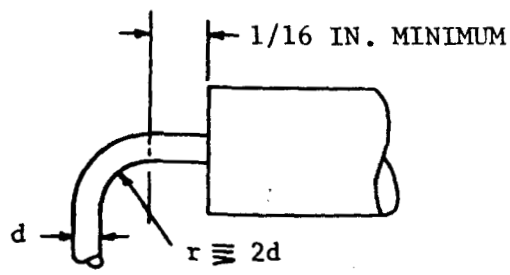



Figure 21. Minimum lead bend.

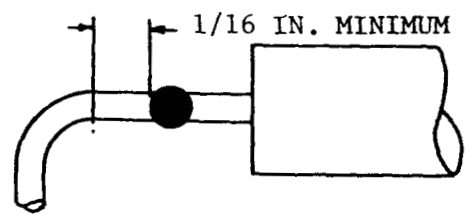



Figure 22. Welded lead with proper bend.

d. Component mounting. - Components shall be preferably parallel to and in contact with the printed circuit board. Irregular shaped components, such as diodes, shall be paralled to the board, and be potted, embedded, or supported by a suitable retaining clamp (see figures 10 and 23a, b, and c). Component leads and other conductors terminated directly at the circuit pad shall extend through the board a minimum of 1/16 inch, or a maximum of 1/8 inch, and shall be clinched parallel to and in contact with the circuit. The bend or clinch shall be in the direction of the circuit pattern (see figure 23d). Unless otherwise shown on the design drawing, components shall be mounted on the side of the printed circuit board which is opposite the printed circuit.

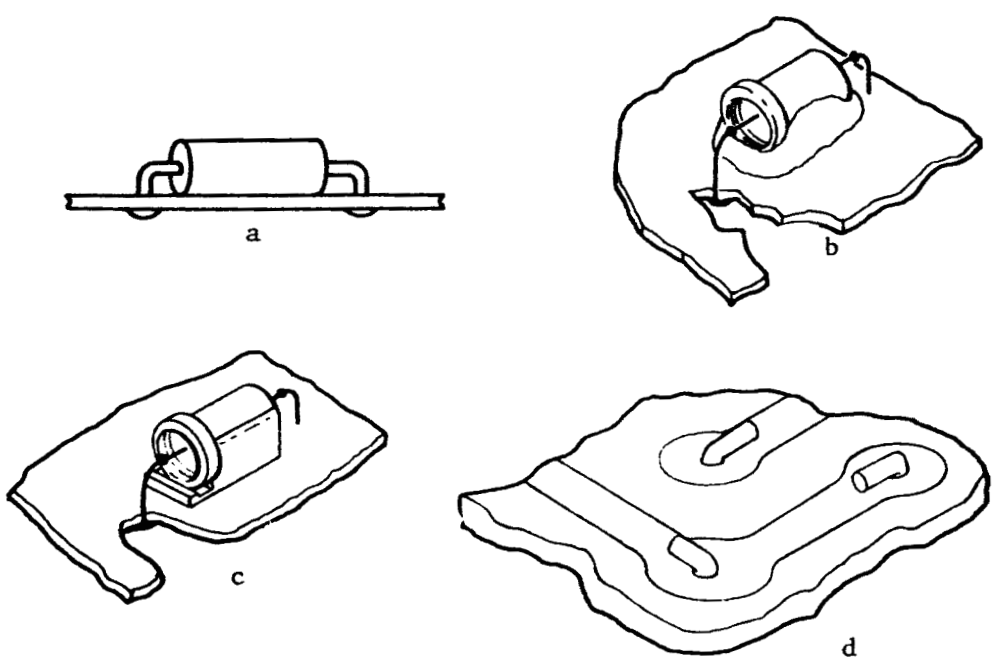



Figure 23. Examples of component mounting.

e. Special mounting. - Component leads that cannot be bent or clinched flush with the circuit shall be properly cleaned and cut to a length that will permit the lead to extend 1/32 inch above the solder pad. Components shall be rigidly secure to the board by means of a suitable mounting clamp or epoxy resin. To minimize this type of connection, components designed for printed circuit application shall be used when obtainable.

f. Solder coverage. - A solder joint shall have a shiny bright appearance, no porosity, good fillet between conductors, good adherence to both parts, and no flux or excess solder. The contour of the wire shall be visible after soldering as shown in figure 10.

g. Boards with circuit pattern on each side. - Component leads that interconnect two-sided circuitry shall be soldered on both sides. Components that are mounted over exposed circuitry shall be insulated as specified by the MSFC design activity.

h. Additional requirements.

(1) Eyelets and tublets shall not be used on printed circuit boards.

(2) Plated-through holes shall not be used unaided as an electrical connection. In plated-through holes where a component lead is not normally installed, insert, bend over, and solder a bus-wire or piece of component lead.

(3) Component parts that weigh 1/4 ounce or more shall be secured by a suitable mounting bracket, potted, or imbedded with an approved epoxy resin.

(4) Pads from which components may be frequently removed shall be reinforced with terminals.

i. Mounting and soldering terminals. - When mounting and soldering terminals to printed circuit boards, the procedure outlined below shall be followed:

(1) Drill the pad hole to a diameter that will permit the terminal shank to be pressed through the board by hand. A press fit is not necessary, but the terminal should not fall out when the board is inverted.

(2) Clean the terminal pad with a white pencil style typewriter eraser or a device of equal material. Apply very light pressure and clean only the pad.

(3) Press the terminal shank through the board and align the terminal as shown in figure 24.

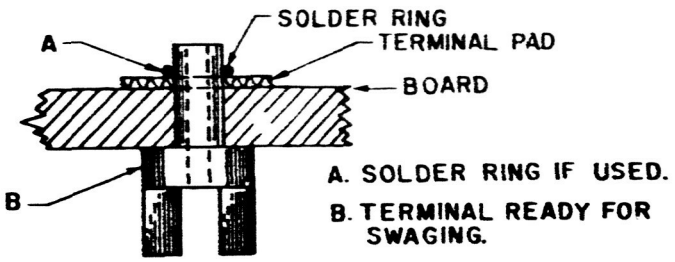



Figure 24. Terminal before swaging.

(4) Make a V-type (funnel) swage on the terminal. The point of the V-swage should enter the terminal shank only far enough to produce a hand-tight fit of the terminal (see figure 25). If solder rings are used, place the ring over the terminal shank before swaging. Solder rings are recommended since they give a more uniform and reliable solder joint.

NOTE

On printed circuit boards where the swaged end of the terminal terminates in a conductor, a V-type swage shall be used. A roll-type swage shall be used elsewhere.

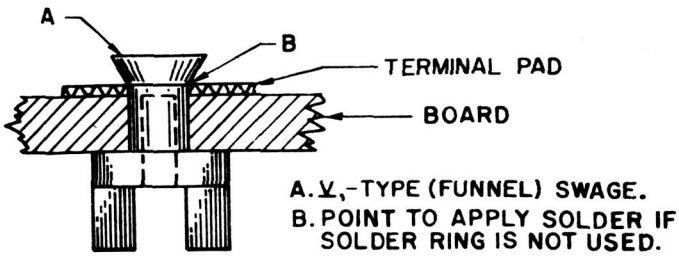



Figure 25. Terminal after swaging.

(5) Place the soldering iron tip over the terminal head as shown in figure 26, and apply solder (if a solder ring is not used) to the joint where the terminal shank and pad intersect. Allow the solder to flow, and then remove the soldering iron tip from the terminal head. The solder should form a neat uniform joint.

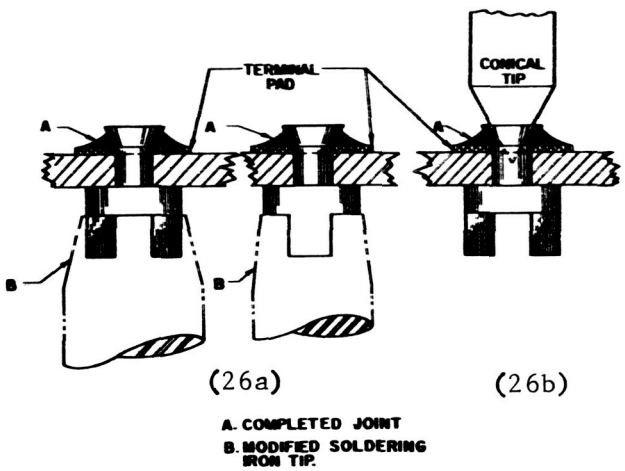



Figure 26. Soldering swaged terminals.

An alternate method may be used; place a conical soldering tip in the barrel of the terminal as shown in figure 26b.

NOTE

The V-type swaging tool point will vary from 18 degrees to 30 degrees as shown in figure 27.

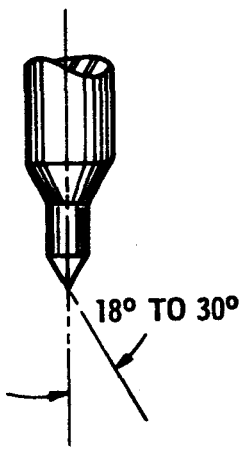



Figure 27. Swaging tool.

(6) Carefully clean the solder joint with an approved solvent and a medium stiff natural or synthetic bristle brush.

(7) Inspect all joints. If any joint should require resoldering, add a small amount of new solder.

j. Coating. - After wiring, functional checkout, and acceptance by inspection, the board shall receive a clean, transparent insulative protective coating on both sides in accordance with Procedure MSFC-PROC-257.

k. Protection. - The printed circuit board shall be placed in a plastic bag between assembly operations and for storage. The plastic bag shall be made of a material that does not emit gases or chemicals that could be detrimental to the solderability of plated circuitry.

Custodian:

National Aeronautics and
Space Administration

Preparing activity:

George C. Marshall Space
Flight Center

APPENDIX

I. Qualification and Certification.

A. Qualification.

1. Qualification of personnel. - All personnel engaged in fabrication, assembly, and inspection of electrical-electronic equipment manufactured under contracts containing this procedure shall be certified by a Category I or II representative prior to performing work on engineering models, prototype models, or production items.

Definition: For the purpose of this procedure "an authorized MSFC representative" shall mean a designated employee of the Government who has successfully completed the instructors course (80 hours) at an approved MSFC school for soldering of reliable electrical connections and who holds a current category I certification card.

2. Demonstration of proficiency. - To achieve certified status, the solder operator shall demonstrate his skill or proficiency according to the requirements set forth herein.

a. Test specimens shall be fabricated in accordance with test specification information found in the Application for Examination of Solder Operators. All test specimens shall be fabricated in the presence of a category I or II representative.

b. After the trainee has demonstrated his ability to the satisfaction of a category I of II representative, a certificate will be issued.

3. Certification categories. - The certificate issued to trainees will show the trainee to be certified in one or more of the following categories.

a. Category I. - Instructor/Examiner. - These are certified Government instructors who have been designated and authorized by MSFC to certify categories III, IV, and V. Candidates for this category must satisfactorily complete the 80-hour instructors course at an MSFC school. Recertification requires satisfactory completion of a 40-hour recertification course at a MSFC school or attendance at an MSFC sponsored soldering seminar.

b. Category II. - Instructor. - These are certified instructors and examiners employed by either supplier or government. Certification and recertification requirements are the same as for Category I.

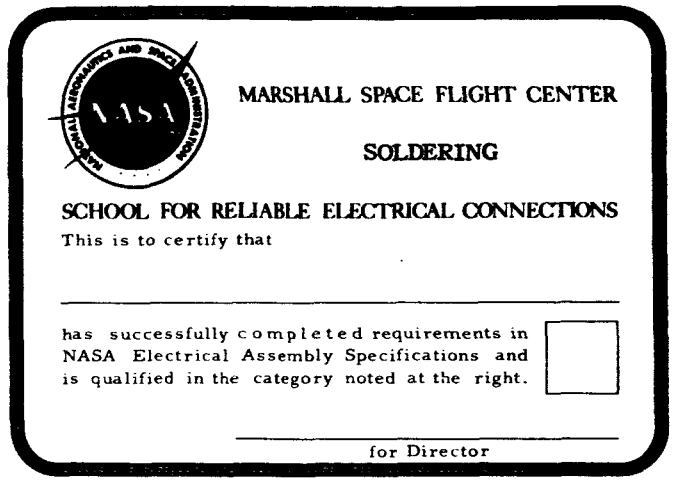
c. Category III. - Operator/Inspector. - This category consists of supplier personnel who have completed the 40 hour course at an MSFC approved supplier school. They shall be required to interpret MSFC specifications and shall have demonstrated the manual skills required by these specifications. Recertification requires either completion of a recertification course at an MSFC approved school, or demonstration to the satisfaction of the certifier that the candidate is still qualified for certification.

d. Category IV. - Inspector (Government). - This category is restricted to government inspection personnel. Certification and recertification requirements are the same as Category I.

e. Category V. - Limited Operator. - Individuals certified to this category are restricted to specified operations, i.e., soldering electrical connectors. It is intended for, but not limited to, supplier personnel who normally perform only one type of operation. To attain certification or recertification, a candidate must demonstrate to satisfaction of the certifier that he is qualified to perform the specified operation.

B. Certification. - If the training report is satisfactory, the quality assurance organization of the cognizant MSFC center will issue a certificate to the operator (see figures 28 and 29). When a supplier is operating an MSFC approved school, a company certificate may be issued by the supplier to its fabrication and inspection personnel and to the personnel of sub-contractors and vendors. The signed certificate, either MSFC or company, will be considered evidence that the applicant has satisfactorily fulfilled all requirements herein. The certificate shall be valid only in the plant of the supplier in whose name the certificate was issued and shall become void twelve months from the date of the last entry thereon or at any time the holder's work is found to be unsatisfactory.

C. Maintenance of certified status. - An operator may retain his certified status by successfully completing re-examination tests every twelve months or by a continuing record of satisfactory workmanship. The authorized MSFC representative may require re-examination testing of any operator whenever he has reason to question the proficiency of the operator or the quality of workmanship. To aid the authorized MSFC representative in determining the proficiency of operators, the supplier shall maintain and make available complete inspection records.



MARSHALL SPACE FLIGHT CENTER

SOLDERING

SCHOOL FOR RELIABLE ELECTRICAL CONNECTIONS

This is to certify that

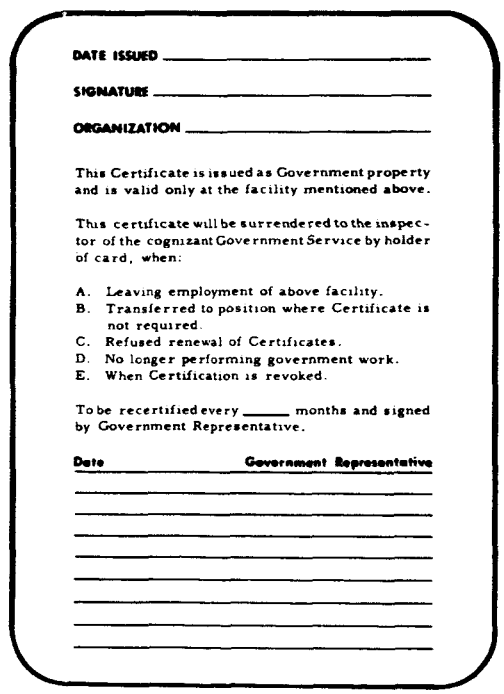
_____

has successfully completed requirements in NASA Electrical Assembly Specifications and is qualified in the category noted at the right.

_____

for Director

Figure 28. Soldering Certification, front side.



DATE ISSUED _____

SIGNATURE _____

ORGANIZATION _____

This Certificate is issued as Government property and is valid only at the facility mentioned above.

This certificate will be surrendered to the inspector of the cognizant Government Service by holder of card, when:

A. Leaving employment of above facility.
B. Transferred to position where Certificate is not required.
C. Refused renewal of Certificates.
D. No longer performing government work.
E. When Certification is revoked.

To be recertified every _____ months and signed by Government Representative.

Date Government Representative

Figure 29. Soldering Certification, reverse side.

D. Training and certification of supplier personnel.

1. Demonstration of ability. - The supplier shall establish a school that follows guidelines established by MSFC. The supplier shall then demonstrate to the satisfaction of the MSFC designated representative that:

a. An efficient training program is being conducted.

b. A close and continuing control over the school will be maintained.

c. Only qualified students will be certified.

The duration of this evaluation shall be determined by the designated MSFC representative.

2. Supplier certification of personnel. - When the supplier has complied with the conditions of paragraph D.1., he will be authorized by the designated MSFC representative to issue certification (see paragraph B.). This authorization may be revoked when:

a. The supplier fails to meet MSFC standards of training.

b. The contract is completed or terminated.